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Comparison of GSM, WCDMA and LTE Performance on 900MHz band

Andreia Ribeiro[I], Nuno Medeiros[I], Nuno Cota[I]

[1] *Instituto Superior de Engenharia de Lisboa (ISEL), Eletronics, Telecomunication and Computer Engineering Department (ADEETC), Rua Conselheiro Emidio Navarro 1, Lisbon 1959-007 , Portugal*

Abstract

With the development of mobile communications, problems associated with interference have emerged, particularly in urban environments, and as a consequence, associated to the performance of the networks. The high values of this demand, lead to the telecommunications operators' need to solve this problem, using the range of frequencies on 900 MHz. The main focus of this work is to evaluate the rate of transmission and spectral efficiency for GSM, WCDMA, and LTE on 900 MHz band. For the purpose of this analysis, a simulator for EDGE and WCDMA was developed, which allows a performance evaluation analysis. For the LTE technology it was used a Vienna LTE Simulator in order to conduct the same type of analysis. In conclusion, LTE is the technology that provides the best results in both simulated performance and network coverage.

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Keywords: GSM; EDGE; WCDMA; LTE; 900 MHz; Simulation of Mobile Communications; Spectral Efficiency; Performance.

1. Introduction

The impetus for the migration to UMTS (*Universal Mobile Telecommunication System*) and LTE (*Long Term Evolution*) on 900 MHz band is due mainly to the possibility of increased radio coverage, available in these lower bands. However, this migration involves the substitution of part of the spectrum allocated to GSM (*Global System for Mobile Communication*) by UMTS and LTE, in order to match the coverage with the existing GSM network, and these will suffer from some limitations in terms of propagation, in particularly the operating bands of higher frequency. From the user's point of view, for the same scenario, it is expected that there is a network with better availability due to better utilization of the power involved.

The objective of this paper is to analyze the performance and the spectral efficiency of the three existing technologies, GSM, UMTS and LTE on 900 MHz band, in a bandwidth of 5 MHz, through simulation. To this end, it will be developed a tool that will assess the key performance indicators of coverage and radio technologies.

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2. Mobile access technologies

2.1. Mobile access technologies aspects

The radio interface is the basis of any mobile communications technology, since it will be the support to communication and mobility of the respective users. The limits of the ability of any mobile system depend on the respective radio interface and particularly the method adopted to ensure the sharing of resources among subscribers. In Table 1 the main aspects of the technologies considered are shown:

Table 1 - Mobile access technologies aspects [1] [2].

Technology	EDGE	UMTS	LTE
Multiple Access	FDMA/TDMA	WCDMA	OFDMA
Maximum Throughput [Mbps]	0,2368 (Multislot 10)	0,936	42,5
Modulation and Codification	MCS	SF	RB

For EDGE (Enhanced Data rates for GSM Evolution), Release 99, it was considered, regarding the transmission of data packets, nine MCS, each one with respective bit rate, depending on the minimum relation of *C/I*, presented in [1], which will be used for calculating of the maximum throughput. In WCDMA (Wideband Code Division Multiple Access), Release 99, it was used a set of predetermined codes, to encode or decode the transmitted information, where it is possible to verify the dependency between the Spreading Factor, the bit rate per channel and the maximum data rate that an user can obtain, in downlink [3]. With the values of Spreading Factor it is possible to reach the relation of *Eb*/*N0*, through the process gain [1].

2.2. Spectrum

The spectrum efficiency depends on the radio interface and transmission, especially the capacity of the system, the techniques used to reduce interference and frequency reuse type. In Table 2 the spectrum of 900 MHz is presented, for the three technologies and respective channel bandwidth.

Table 2 - Spectrum configuration for each technology [4] [5].

Technology	Uplink [MHz]	Downlink [MHz]	Channel Bandwidth [MHz]
EDGE	880-915	925-960	0.2
UMTS	880-915	925-960	5
LTE	880-915	925-960	5

3. Simulation Model

The simulation was developed using the MatLab in order to implement EDGE and WCDMA technologies, applying calculations of Link Budget [1], to assign, subsequently, the services to users in the area under study.

3.1. Architecture simulator

The process of developing the simulator was based on the objectives set for the end use of the program:

- Analysis of losses and radio coverage;
- Analysis of the occupation of resources;
- Analysis of interference;
- Analysis of network performance.

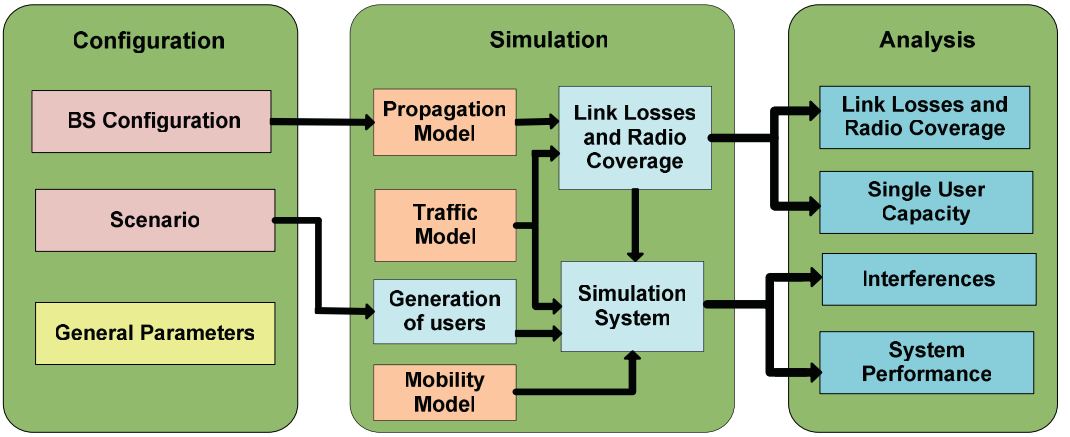

Figure 1- Simulation tool.

The simulator developed consists of three distinct and successive stages as described in Figure 1. In the Configuration process it is performed all the design and initial setting of the system, including the configuration of the BSs (Base Stations) and the definition of scenarios. The Simulation process is composed by the mobility, traffic and propagation models, in order to perform the radio coverage calculations and the system simulation. The Generation of users is only applied in the Multiple users model, which is generated a grid, where users are distributed and each one of them is requiring a certain service. In the Analysis process it is possible to observe the final results, through graphics based on the results obtained in the previous process.

3.2. Propagation model

The path loss is calculated using the Link budget derived from the Okumura Hata propagation model [2] (1), for the urban model, not considering the obstacles between transmitters and receivers.

$$Lu_{[dB]} = 69.55 + 26.16 \cdot \log(f_{[MHz]}) - 13.82 \cdot \log(Hb) - 3.2 \cdot [\log(11.75 \cdot Hm)]^2 - 4.97 + \\ + [44.9 - 6.55 \cdot \log(Hb)] \cdot \log(d_{[km]}) \quad (1)$$

The following images present link losses for both scenarios under consideration:

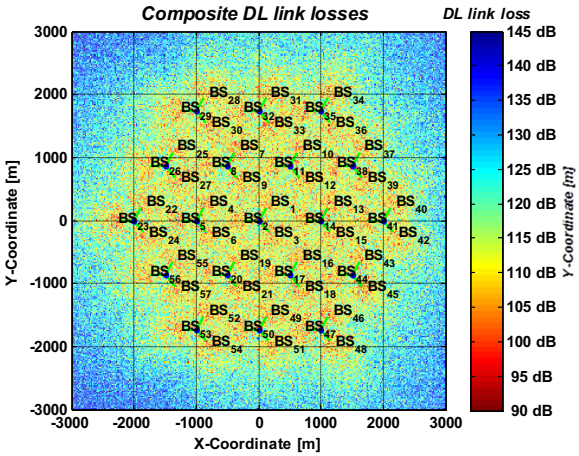

Figure 2 - Link losses, for microcellular scenario.

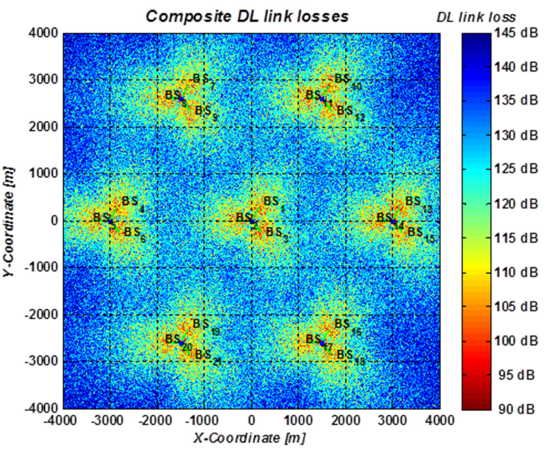

Figure 3 - Link losses, for macrocellular scenario.

Figure 2 and 3 present the link losses, considering total losses of all BSs, on the reference scenarios, where the ranging values are 90 to 140 dB, approximately. These values derive from the fact that they use a considerable quantity of BSs, which lead to a reduced cell radius.

Regarding simulation, two models has been used for performance evaluation: single and multiple users. In the Single user model, an evaluation of the maximum cell radius is realized, which is the maximum distance that allows the user to be served with the requested throughput when the user is alone in the cell. In order to get the capacity, through the value of the sensitivity, it is necessary to calculate link losses, to know how much power is received at each pixel on the map to each BS. With these values, a comparison was made between BSs to find the Best Server, in order to know the relations of *C/I* and *Eb/N0*. After the coverage analysis, it is possible to get, through output variables from simulator, the various analysis options like Best Server, RX-Level, *C/I* and throughput. Contrary to the Single user simulator, the Multiple Users simulator have the purpose to approximate the simulations to the realistic scenario, for downlink, where multiple users request for different types of service, with different bit rates. In the Multiple users model all parameters of Single user model are considered, and with the respective values of minimum throughput for each service, and it is compared if that user can have the required service. Depending on the selection of the type of distribution, Voice Centric or Data Centric, this option will display the initial distribution of existing users, where each user requires the respective service. It is also possible to preview the distribution of the users who are, or not, covered with required service. In order to get the LTE simulations, it was used the simulator developed by [6] [7]. The simulations were performed in order to know the average throughput and maximum throughput as a function of *SINR* for later analysis of the spectral efficiency.

4. Results and discussion

4.1. Scenarios

The simulations were implemented according to Table 3, where the region of study, the number of BSs and the orientation of the antennas are considered. In Single user model it was considered that there is only one user in the cell, therefore, all the available resources are allocated to this user. This scenario was used to calculate the maximum cell radius for the chosen throughput. In the Multiple users model, it was considered the existence of 1000 users and that they are randomly distributed along the coverage area of the BS, performing six different services with different bit rates. Two distributions were considered, Voice Centric and Data Centric, with more focus on voice and data respectively. In Table 4 is shown the percentage of users that require one type of service, depending on the technology and distribution.

Table 3 - Parameters of Simulator Network [1].

Scenario	Region [m]	Base Station	Antennas
Macrocellular	8000 x 8000	21	Opening 65º and oriented 0º, 120º and 240º
Microcellular	6000 x 6000	57	

Table 4 - Profiles of Voice and Data Centric for the technologies on study [1].

		Users Voice Centric [%]		Users Data Centric [%]
Services	Minimum Throughput [Mbps]	EDGE	WCDMA & LTE	WCDMA & LTE
Voice	0.0122	83.6	50	20
Video Call	0.064	4.2	10	10
MMS	0.03	12.2	---	---
Streaming	0.456	---	10	20
FTP	0.936	---	20	30
HTTP	0.936	---	10	20

4.2. Single User Results

The Figure 4 and 5 show that the dimension of the radius of coverage is higher for the macrocellular scenario due to the increased spacing between BSs.

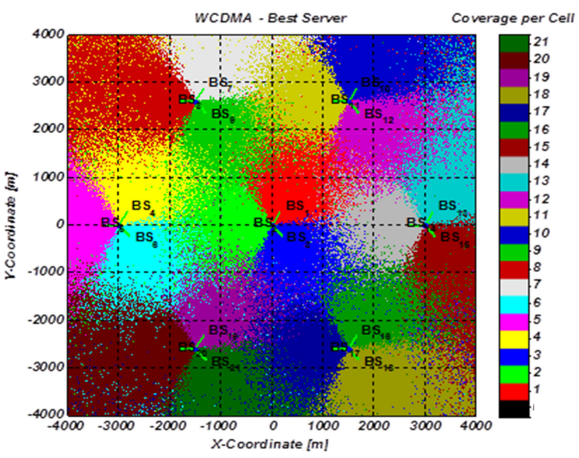

Figure 4 - Best Server in macrocellular scenario.

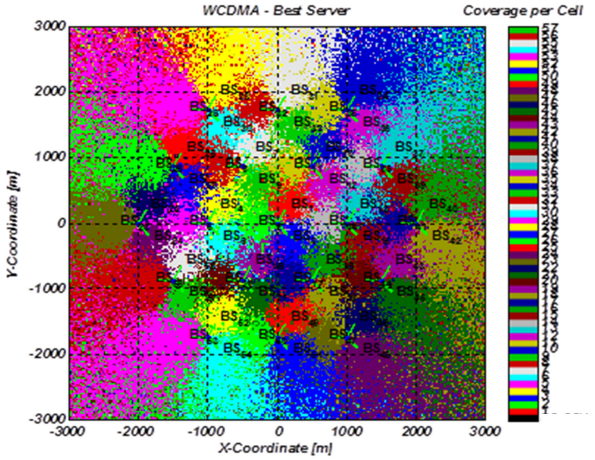

Figure 5 - Best Server in microcellular scenario.

In the Single user scenario, the throughput depends directly on the *C/I* and *Eb/N0*, respectively for EDGE and WCDMA, considering that in each pixel of the map the maximum throughput is calculated. In macrocellular scenario the decrease on throughput is more perceptible, along the radius of the cell, compared with microcellular scenario, where the distances between BSs are lower. Therefore, one obtains values of maximum throughput of about 236.8 kbps for EDGE, and 0.936 Mbps for WCDMA.

Hence, the applicational throughput, for Figure 6, presents a nearly constant value until at 0.5 km radius and for Figure 7 approximately 1.5 km, which is in accordance with the desired results for Single user model.

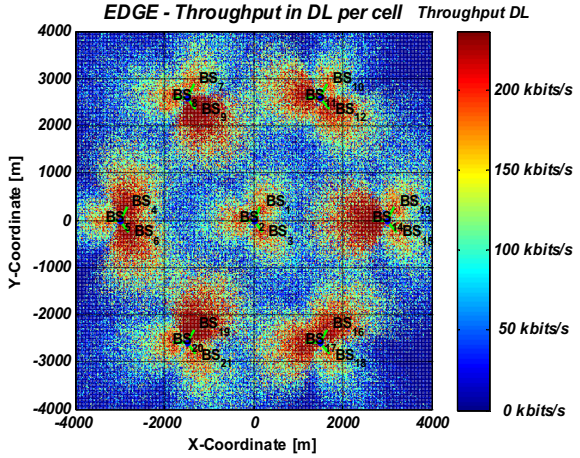

Figure 6 - EDGE - Throughput in macrocellular scenario.

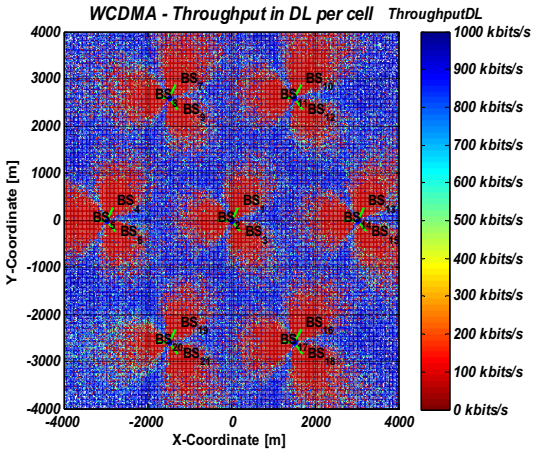

Figure 7 - WCDMA - Throughput in macrocellular scenario.

4.3. Multiple User Results

Through of the obtained throughput, it is possible to know if the user could have, or not, the requested service, considering the minimum values as presented on the Table 5. The main difference is focused on the increase of one user, compared with a macrocellular scenario, and with a raise of 3% on MMS service, since the microcellular scenario takes the advantage on the users that are closer of the base stations.

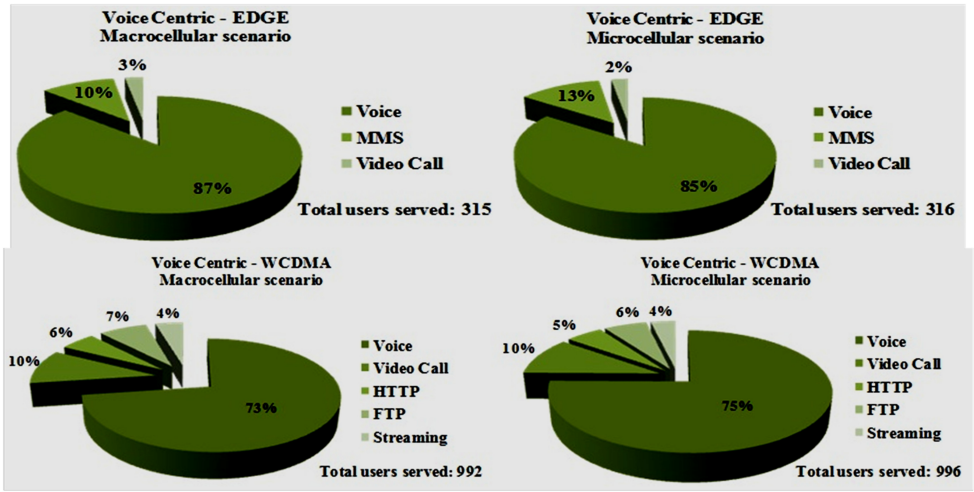

Figure 8 - Services allocation distribution for Voice Centric, in EDGE and WCDMA.

With the services distribution presented on Figure 8, it could be confirmed that exists more coverage on voice services with about of 3/4 of users served, that proves voice centric distribution has more focus on voice services given for respective users. On the other hand, in Figure 9, for macrocellular, it exists a majority of given data services, with approximately 52% of 992 of the users served. In microcellular scenario, this concept is not so noticeable, with 42% of users, since on this scenario some of the users are far from the large concentration of BSs, so they couldn't take bigger values of *Eb/N0* sufficient for data services.

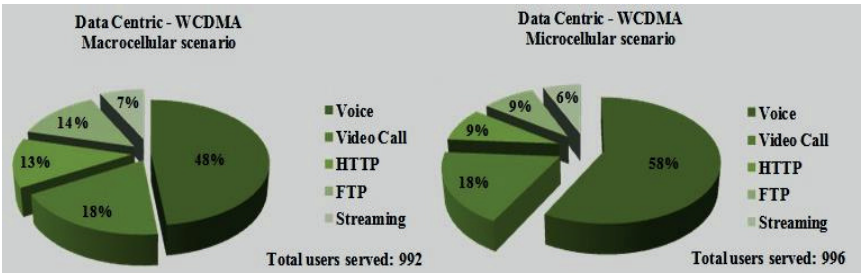

Figure 9 - Services allocation distribution of services users for Data Centric, in WCDMA.

The values of spectral efficiency are presented in Table 5, the average and maximum throughput, obtained by the simulator developed by Institute of Communications and Radio-Frequency Engineering, of the Vienna University of Technology. For a Voice and Data centric distribution, the values of spectral efficiency are higher in microcellular scenario, caused by the difference of the number of BSs in the map, thereby creating a better use of bandwidth used by BSs. In what regards the average and maximum throughput values, these are obtained from the lower radius coverage, available on microcellular scenarios, which have influence on maximum throughput offered by each BS.

Table 5 - Throughput and Spectral efficiency results in macrocellular and microcellular scenario [1].

Scenario	Macrocellular		Microcellular	
Distribution	Voice Centric	Data Centric	Voice Centric	Data Centric
Average Throughput	0.39 Mbps	0.39 Mbps	0.74 Mbps	0.73 Mbps
Maximum Throughput	1 Mbps	1.05 Mbps	2.07 Mbps	2.15 Mbps
Spectral efficiency	0.2 bit/Hz	0.21 bit/Hz	0.41 bit/Hz	0.43 bit/Hz

4.4. Comparison between technologies

As expected the Voice Centric distribution, for the three technologies, contains lower bit rates compared to the Data Centric, as is presented in Figure 10. For microcellular scenario, it's possible to obtain higher average bit rates per user, especially for LTE, which reaches 0.75 Mbps, since the macrocellular scenario is only evaluated on the ROI (Region Of Interest).

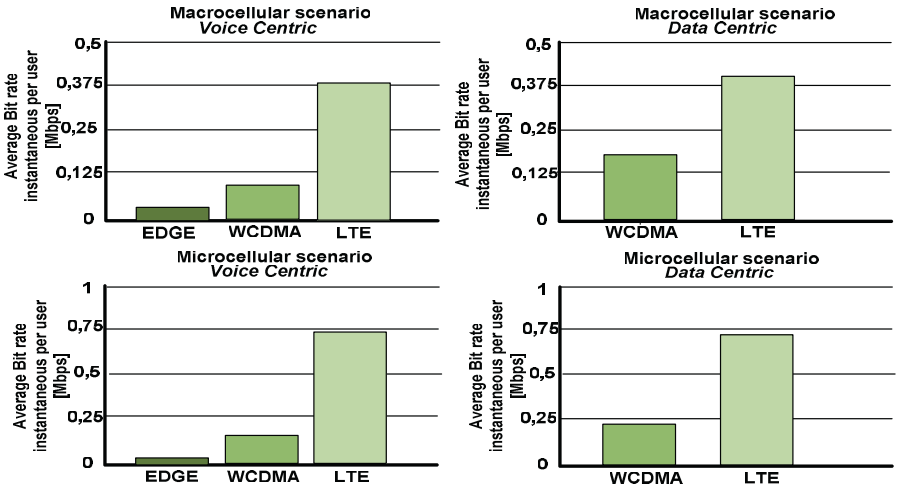

Figure 10 - Average bit rate instantaneous per user between technologies, for Macrocellular scenario [1].

The spectral efficiency is obtained by the ratio between the maximum output obtained and the bandwidth of 5 MHz As seen in Figure 11, for the services of Voice and Data Centric, LTE have higher values comparing with the remaining technologies, because of the higher throughput reached. In Data Centric distribution had a small increase in spectral efficiency, since the output values are higher.

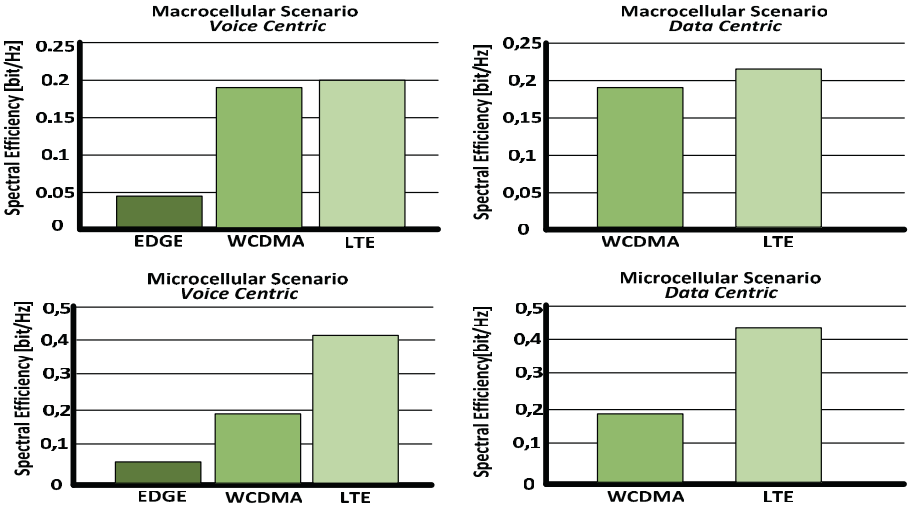

Figure 11 - Spectral Efficiency between technologies, for Macrocellular and Microcellular scenarios [1].

5. Conclusions

This paper concerns the comparison between EDGE, WCDMA and LTE on 900 MHz band, focused on the performance and the spectral efficiency. In Single user model, it was observed that for the EDGE, with the introduction of BSs in the scenario, there is an increase of interferences, which affect the higher received power and consequently, less throughput. In order to reduce this interference, it was considered the frequency reuse factor equal to three, reducing those interferences at the same communication channel, resulting in better network performance. The WCDMA technology uses the orthogonality factor, which aims reducing the noise created by the cell itself. In Multiple users model, the scenarios in question were simulated, in order to visualise the results from the existence of users with the appropriate service required. The resulting values show that users, who are outside of the area of coverage, get more voice service, since they are far from respective BS. Through simulations, for a Voice Centric distribution, LTE achieves a maximum bit rate, reaching 2.07 Mbps and in Data Centric to 2.15 Mbps, thus concluding that LTE is the technology which offers the best values in throughput and consequently spectral efficiency in the 900 MHz band.

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